Edexcel Biology GCSE

Topic 8: Exchange and Transport in Animals

Notes

(Content in bold is for higher tier only)

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8.1 - Transporting Substances

It is necessary to transport substances into organisms which are vital for life, and to transport waste products out of the organism to prevent them **accumulating.**

For example, plants need to be highly specialised at taking in oxygen and transporting carbon dioxide (a waste product of photosynthesis out), while at the same time being able to take in **dissolved nutrient and mineral. molecules** and **water** from the soil and air.

Animals have especially advanced systems to remove waste - such as the kidney, which was discussed in Section 7. The kidney efficiently removes waste such as urea and excess ions. This is vital, as if excess urea is not removed it builds up in the body and becomes **toxic**. Excess carbon dioxide can also build up and dissolve in the blood, causing it to become **acidic -** leading to a condition called **acidosis**.

8.2 - Exchange Surfaces and SA: Volume Ratio

Specialised exchange surfaces allow efficient transport of substances from one area to another (from **outside** to inside the organism, for example). Exchange surfaces often have a **short distance for diffusion** and **a large surface area.** Some exchange surfaces include:

- **The root hair cells of plants:** these are specialised to take up water and nutrients from the soil, as they have a large surface area and thin walls (meaning diffusion across the wall into the plant can occur quickly)
- **The walls of the nephrons in the kidney:** these also have thin walls and a very large surface area, as they are required to efficiently reabsorb substances like water and glucose.
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- In the lungs, oxygen is transferred to the blood and carbon dioxide is transferred to the lungs. This takes place across the surface of millions of air sacs called **alveoli**, which are covered in tiny **capillaries**, which supply the blood.
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- In the small intestine, cells have projections called **villi**. Digested food is absorbed over the membrane of these cells, into the bloodstream.
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- The gills are where gas exchange takes place in fish. Water which has oxygen passes through the mouth and over the gills. Each gill has plates called **gill filaments**, and upon these are **gill lamellae**, which is where diffusion of oxygen into the blood and diffusion of carbon dioxide into the water takes place. Blood flows in one direction while water flows in the other.
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- In the leaves of the plant there are many different tissues to aid with gas exchange. Carbon dioxide diffuses through **stomata** for photosynthesis, whilst oxygen and water vapour move out through them. The stomata are controlled by guard cells, which change the size of the stomata based on how much water the plant received (the guard cells swell with lots of water and make the stomata larger)

Adaptation	Why?	Example
Having a large surface area	The greater the surface area, the more particles can move through, resulting in a faster rate of diffusion	Lungs: the small, spherical **alveoli** (sites of gaseous exchange) in the lungs create a very large surface area (approximately $75m^2$ in humans). Small intestine: the cells of the small intestine have millions of **villi**, which are projections which increase the surface area. This means digested food can be absorbed into the blood faster Fish gills: these contain lamellae to increase the surface area. Leaves: the flattened shape increases the surface area. The air spaces inside the leaf increase the surface area, so more carbon dioxide can enter cells.
Having a thin membrane	Provides a short diffusion pathway, allowing the process to occur faster	Lungs: alveoli and capillary walls are extremely thin. Small intestine: villi have a single layer of surface cell.
Having an efficient blood supply/being ventilated (in animals)	Creates a steep concentration gradient, so diffusion occurs faster	Lungs: the lungs constantly supply oxygen to make the blood from alveoli capillaries **oxygenated**, by exchanging it for carbon dioxide that can be breathed out. This is a constant process meaning the concentration gradient is always steep. Fish: water flows in one direction and blood flows in the other - this means that a steep concentration gradient is maintained as the concentration of oxygen is always much higher in the water - so it will diffuse across.

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An important measure of how well an organism or cell can transport substances is the **Surface Area to Volume Ratio.** This is the size of the surface area of the organism compared to its volume

- Calculated by finding the volume (length x width x height) and the surface area (length x width), and writing the ratio in the smallest whole numbers
- If this is large, the organism is less likely to require specialised exchange surfaces and a transport system because the rate of diffusion is sufficient in supplying and removing the necessary gases
- E.g 15 (surface area): 5 (volume) is written as 3:1

Single-celled organisms can use diffusion to transport molecules into their body from the air- this is because they have a relatively large **surface area to volume ratio**. Due to their low metabolic demands, diffusion across the surface of the organism is sufficient enough to meet its needs.

In **multicellular organisms** the surface area to volume ratio is small so they cannot rely on diffusion alone. Instead, surfaces and organ systems have a number of adaptations that allows molecules to be transported in and out of cells.

- Larger organisms often have a small surface area to volume ratio, as they have a **large volume but relatively small surface area.**
- Smaller organisms have a larger surface area to volume ratio, as they have a large volume relative to their surface area.

The greater the surface area to volume ratio, the better adapted the organism is for diffusion. If an organism increases its surface area, it can take in more nutrients and expel more waste products more efficiently.

8.3 - Adaptations of Alveoli

Alveoli are the small **'air sacs'** in the lungs. They are surrounded by blood vessels with thin walls, allowing gas exchange **between the lungs and blood**. Alveoli are adapted for this to take place in a number of ways:

- They are very small and arranged in clusters, creating a large surface area for diffusion to take place over
- The capillaries provide a large blood supply, maintaining the concentration gradient
- The walls of the alveoli are very thin, meaning there is a short diffusion pathway

8.4B - Factors affecting Rate of Diffusion

Many factors affect the rate of diffusion:

Factor	Effect
Concentration gradient (difference in concentrations)	The greater the difference in concentration, the faster the rate of diffusion. This is because more particles are randomly moving down the gradient than are moving against it.
Temperature	The greater the temperature, the greater the movement of particles, resulting in more collisions and therefore a faster rate of diffusion.
Surface area of the membrane	The greater the surface area, the more space for particles to move through, resulting in a faster rate of diffusion.

8.5B - Calculating Rate of Diffusion

You should be able to calculate the rate of diffusion given surface area, difference in concentration between the two substances either side of a membrane, and the thickness of a membrane:

$$\text{rate of diffusion} \ \alpha \ \frac{\text{surface area} \times \text{concentration difference}}{\text{thickness of membrane}}$$

□ means ‘is proportional to’

8.6 - Blood Structure and Function

Blood is made up of plasma, red blood cells, white blood cells and platelets.

1. **Plasma**
    - This is liquid that carries the components in the blood: red blood cells, white blood cells, platelets, glucose, amino acids, carbon dioxide, urea, hormones, proteins, antibodies and antitoxins
2. **Red blood cells**
    - They carry oxygen molecules from the lungs to all the cells in the body
    - Their biconcave disc shape provides a large surface area
    - They have no nucleus allowing more room to carry oxygen
    - They contain the red pigment haemoglobin, which binds to oxygen and forms oxyhaemoglobin
3. **White blood cells**
    - They are a part of the **immune system**, which is the body's defence against pathogens (microorganisms that can produce disease)
    - They have a nucleus
    - There are a number of types:
        - 1- Those that produce **antibodies** (small proteins that clump them together) against microorganisms
        - 2- Those that engulf and digest pathogens
        - 3- Those that produce antitoxins to neutralise toxins (poisons) produced by microorganisms
4. **Platelets**
    - They help the blood clot form at the site of a wound
    - The clot dries and hardens to form a scab, which allows new skin to grow underneath while preventing microorganisms from entering
    - Small fragments of cells
    - No nucleus
    - Without them, cuts would result in excessive bleeding and bruising

8.7 - Structure and Function of Blood Vessels

The body contains three different types of blood vessel:

1. **Arteries** carry blood AWAY from the heart
    - Layers of muscle in the walls make them strong
    - **Elastic fibres** allow them to stretch
    - This helps the vessels withstand the high pressure created by the pumping of the heart
2. **Veins** carry blood TOWARDS the heart
    - The **lumen** (the actual tube in which blood flows through) is wide to allow the low pressure blood to flow through
    - They have valves to ensure the blood flows in the right direction

3. **Capillaries** allow the blood to flow very close to cells to enable substances to move between them
    - One cell thick walls create a short diffusion pathway
    - Permeable walls so substances can move across them

8.8 - Heart and Circulatory System Structure and Function

The heart is an organ in the **circulatory system**. The circulatory system carries oxygen and nutrients to every cell in the body and removes the waste products.

The heart pumps blood around the body in a **double circulatory system**. This means there are two circuits.

- 1: Deoxygenated blood flows into the **right atrium** and then into the **right ventricle** which pumps it to the lungs to undergo gaseous exchange
- 2: Oxygenated blood flows into the **left atrium** and then into the **left ventricle** which pumps oxygenated blood around the body

Structure of the heart:

- Muscular walls to provide a strong heartbeat
- The muscular wall of the left ventricle is thicker because blood needs to be pumped all around the body rather than just to the lung like the right ventricle.
- 4 **chambers** that separate the oxygenated blood from the deoxygenated blood
- **Valves** to make sure blood does not flow backwards
- **Coronary arteries** cover the heart to provide its own oxygenated blood supply

Process:

1. Blood flows into the right atrium through the **vena cava**, and left atrium through the **pulmonary vein**.
2. The atria contract forcing the blood into the ventricles.
3. The ventricles then contract, pushing the blood in the right ventricle into the **pulmonary artery** to be taken to the lungs, and blood in the left ventricle to the **aorta** to be taken around the body.
4. As this happens, valves close to make sure the blood does not flow backwards.

The **natural resting heart rate** (around 70 beats per minute) is controlled by a group of cells found in the right atrium that act as a **pacemaker**- they provide stimulation through small electrical impulses which pass as a wave across the heart muscle, causing it to contract. Without this, the heart would not pump fast enough to deliver the required amount of oxygen to the whole body.

An **artificial pacemaker** can be used if the individual has an irregular heartbeat. It is an electrical device that produces a signal causing the heart to beat at a normal speed.

8.9 - Cellular Respiration and 8.10 - Anaerobic and Aerobic Respiration

Respiration occurs in every cell in the body, and it is the process of transferring energy from glucose so living processes can occur. All living things undergo respiration.

- It is **exothermic** as energy is transferred to the environment
- It can take place **aerobically** (with oxygen) or **anaerobically** (without oxygen)

Aerobic respiration	Anaerobic respiration
This uses oxygen. It yields the most energy. Most of the reactions that make up aerobic respiration occur in the mitochondria. **$C_6H_{12}O_6 + O_2$ ---> $CO_2 + H_2O$** **$C_6H_{12}O_6$ = glucose** **O_2 = oxygen** **CO_2 = carbon dioxide** **H_2O = water**	Occurs when there is not enough oxygen. It does not yield as much energy as aerobic respiration. It is only used as a last resort, for example during a sprint where it is difficult to breathe in enough oxygen. The oxidation of glucose is complete. In animals: **Glucose ($C_6H_{12}O_6$) ---> Lactic acid** In plant and yeast cells it is called fermentation): **Glucose ($C_6H_{12}O_6$) ---> Ethanol + Carbon dioxide (CO_2)** This reaction is used to make bread and alcoholic drinks.

8.11 - Core Practical: Investigate the rate of respiration in living organisms

In this practical, we will build a simple **respirometer** - a machine to measure the effect of temperature on the oxygen consumption of small organisms.

1. Pick a small organism that you would like to measure the rate of respiration of (e.g maggots, or leaves)
2. Place 5cm^3 of soda lime into a test tube.
3. Place gauze on top and a small amount of the organism being tested on top of this.
4. Attach a three-way tap, capillary tube and syringe to the test-tube. Plug the test-tube with a stopper.
5. Insert a small amount of coloured liquid into the capillary tube.

6. Turn the 3-way tap to allow air to enter the test tube for 5 minutes. After 5 minutes, close the 3-way tap.
7. Record how far the coloured liquid has moved against a scale.

8.12 - Measuring Cardiac Output

We can measure how well the heart is working by using the following equation:

$$\text{cardiac output} = \text{stroke volume} \times \text{heart rate}$$

Stroke volume is the volume of blood expelled from the heart in one contraction, whereas heart rate is the number of contractions (beats) per minute.